Development Of An Expert System Based On The Systematic Approach To Tropical Cyclone Track Forecasting

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LONG-TERM GOALS

The long-term goals of this project are to improve the quantitative accuracy and interpretative utility of official tropical cyclone (TC) track forecasts by enabling forecasters to successfully recognize and skillfully compensate for periods when numerical TC track forecast models are likely to be making highly erroneous track forecasts. The conceptual methodology for accomplishing these goals is the Systematic Approach to Tropical Cyclone Track Forecasting (hereafter Systematic Approach) conceived by Carr and Elsberry (1994).

OBJECTIVES

The specific objectives of this project are to: (i) develop a prototype expert system based on the Systematic Approach; and (ii) demonstrate the feasibility of such an expert system for improving the accuracy and meteorological utility of official tropical cyclone track forecasts. It is emphasized that the purpose of the expert system is not to replace the human forecaster, but to proactively lead the forecaster through a methodical process of numerical guidance evaluation and forecast formulation that produces consistently skillful official track forecasts.

APPROACH

Following the conceptual framework of the Systematic Approach (Fig. 1), the expert system will be a series of inter-linked software modules that assist the forecaster to accomplish each of the three main processes. To field a prototype expert system as expeditiously as possible, software development commenced with the module that implements Phase II. Subsequent versions will incorporate Phases I and II.

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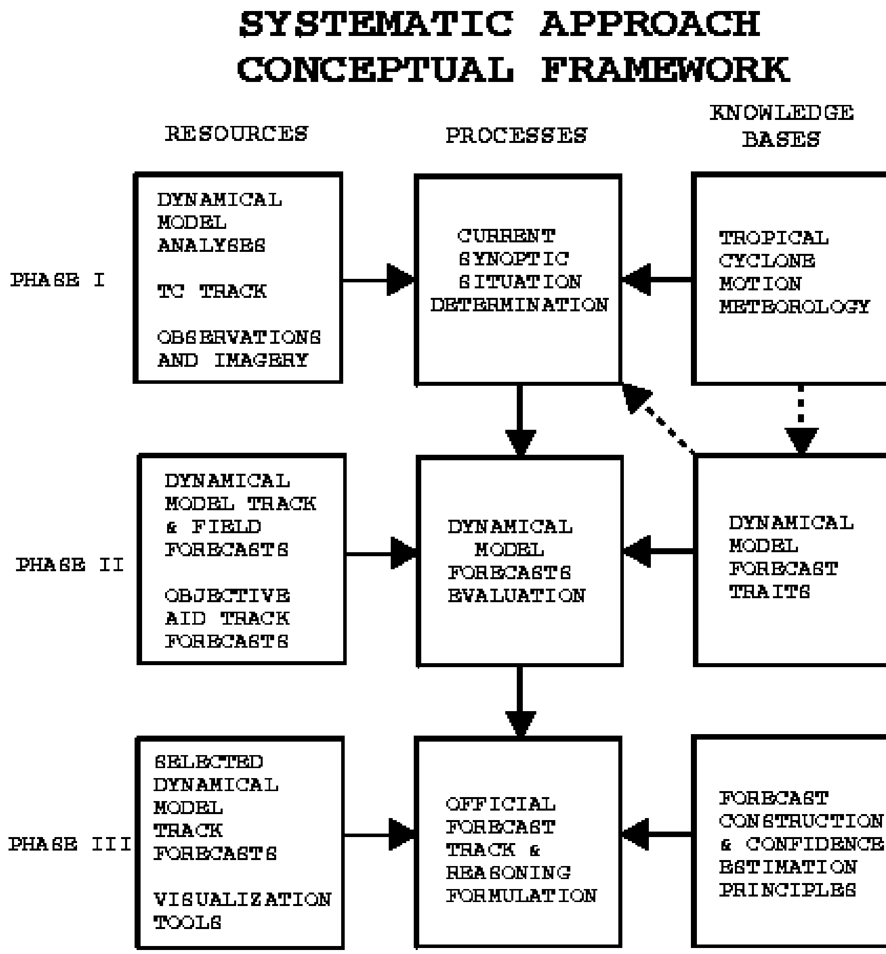

Figure 1. Schematic of the Systematic Approach procedural framework, including the three main decision-making procesess and the associated information resources and knowledge bases.

WORK COMPLETED

A testable expert system prototype (Peak et al. 2000) that implements Phase II (Fig. 1) was completed in July 1999 for real-time utilization and evaluation at the Naval Postgraduate School (NPS). The critical Model Traits Knowledge Base for the prototype is contained in Carr and Elsberry (1999, 2000a,b). At the request of JTWC, NPS agreed to name the expert system the Systematic Approach Forecasting Aid (SAFA). A beta test of the SAFA prototype was conducted at NPS by a team of researchers and forecasters from 23 August to 1 December 1999, which covered TC 19W through 30W. The results of the beta-test are documented in Carr et al. (2000a,b,c). Based on the results, a number of refinements were made to the SAFA software, and several web browser-based training modules were developed for forecaster familiarization and proficiency with the initial operational version of SAFA that was fielded in July 2000.

RESULTS

Key objectives of the beta test by NPS were to: (i) validate the error mechanism frequencies suggested by previous research associated with this project (Carr and Elsberry 1999, 2000a,b,c); (ii) determining whether error mechanisms could be correctly identified without the benefit of hindsight; and (iii) documenting that a selective consensus (SCON) track forecast that excludes dynamical model tracks deemed to be unacceptably erroneous is more accurate that a non-selective consensus (NCON) forecast that includes all available dynamical model track forecasts.

With regard to (i) and (ii) above, Table 1 provides error mechanism totals summed over all models, as well as the number of misses and false alarms made by the NPS beta-test team. In general, the error frequencies are similar to those in Carr and Elsberry (1999) with Excessive-Direct Cyclone Interaction (E-DCI) being the most frequent error mechanism. Other frequently occurring error mechanisms in the developmental sample such as Excessive-Ridge Modification by a TC (E-RMT), Excessive-Reverse Trough Formation (E-RTF), and Excessive-Response to Vertical wind Shear (E-RVS) also occurred frequently during the beta test. These four frequently occurring error mechanisms (E- DCI, E-RMT, E-RTF, E-RVS) were generally recognized successfully by the NPS beta-test team. That is, the numbers of misses and false alarms are significantly smaller than the number of occurrences of each error mechanism (Table 1). In the cases of E-DCI and E-RMT, the false alarm rates are higher than desired. However, several false alarms for these mechanisms were for model track forecasts that were indeed degraded, but the degradation did not result in a 72-h error greater than 300 n mi.

ERROR MECHANISM NAME		Total number of Occurrences	Misses	False Alarms
Direct Cyclone Interaction	**DCI**	**29**	**1**	**7**
Semi-direct Cyclone Interaction	SCI			
SCI on Western TC	SCIW			
SCI on Eastern TC	SCIE	0	0	2
Indirect Cyclone Interaction	ICI			
ICI on Eastern TC	ICIE	1	0	0
ICI on Western TC	ICIW	2	2	1
Ridge Modification by TC	**RMT**	**8**	**1**	**3**
Reverse Trough Formation	**RTF**	**8**	**3**	**1**
Response to Vertical wind Shear	**RVS**	**8**	**1**	**0**
Baroclinic Cyclone Interaction	*BCI*	*4*	*4*	*0*
Midlatitude System Evolutions	MSE			
Midlatitude CycloGenesis	*MCG*	*2*	*0*	*4*
Midlatitude CycloLysis	MCL			
Midlatitude AnticycloGenesis	MAG	3	1	0
Midlatitude AnticycloLysis	MAL	1	0	0
Monsoon Gyre-TC Interaction	*GTI*	*3*	*3*	*0*
Not discernible or explainable		13	1	1

Table 1. Total occurrence (column 3) of various error mechanisms (regardless of whether character is excessive or insufficient), misses by NPS beta-test team (column 4), and false alarms by NPS beta-test team (column 5) during the period of the SAFA beta-test. Rows in bold (italics) indicate error mechanisms for which a low (high) incidence of misses or false alarms occurred.

The third objective of the beta test was to demonstrate that, on average, a SCON track after deletion of one or more dynamical model tracks will have smaller errors than the NCON track. Figure 2 depicts a case for which SCON was a marked improvement over NCON, which illustrates the considerable value-added that can be achieved using SAFA. To assess the average performance of SCON relative to NCON during the SAFA beta test, only a relatively small sample is available: 61, 46, and 29 forecasts at 24, 48, and 72 h, respectively. The rapid fall-off of the sample size with increasing forecast interval indicates that TCs 19W to 30W were relatively short-lived so that often a verifying position was not available, especially at 72 h. For the 29 cases at 72 h, the FTEs for the CLIPER, JTWC, NCON, and SCON were 305, 220, 205, and 200 n mi, respectively. Thus, both SCON and NCON forecasts were an improvement over the official forecasts, and about 100 n mi better than the CLIPER, which is then considered as a 33% skill.

As it became evident that only a small average SCON-NCON difference was being achieved when some individual cases of marked improvement of the SCON track relative to the NCON track had been achieved, a mid-test evaluation was made as to the cases when the SCON errors were greater than the NCON errors. In seven of these eight cases, the consensus spread of the dynamical model tracks relative to the NCON position was less than 250 n mi, which the data of Elsberry and Carr (2000) suggest may be a threshold for a relatively tight cluster.

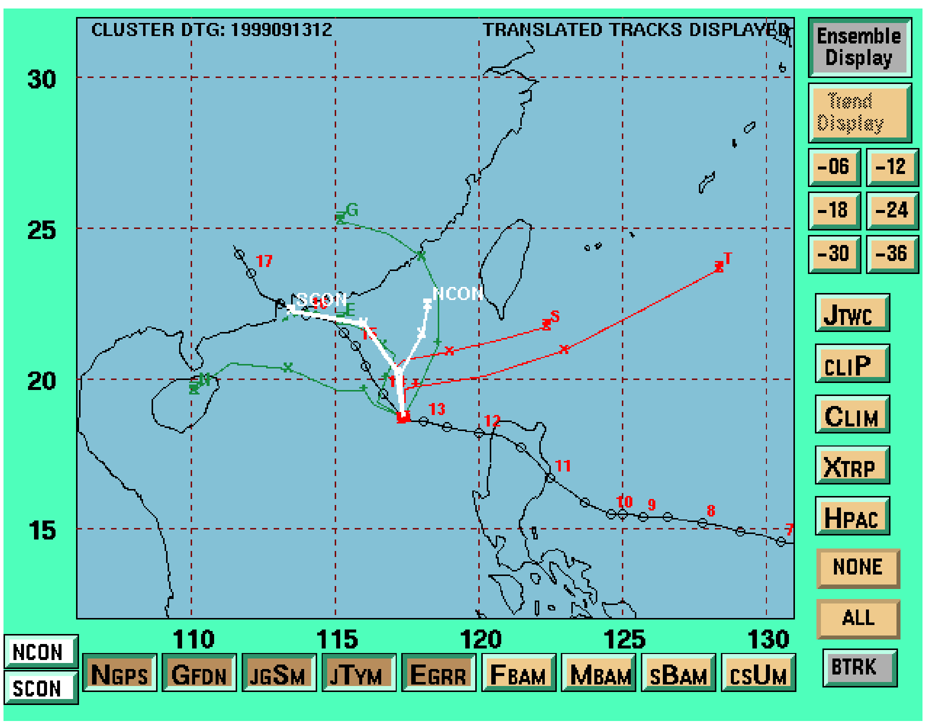

Figure 2. Screen capture of the Tracks Display portion of the SAFA screen showing a SCON forecast (average of green "accepted" dynamical model tracks) that is considerably more accurate than the NCON forecast (average of all five tracks). The two red tracks were rejected by the NPS beta test team due to recognized indications of Excessive Reverse Trough Formation (E-RTF) in the forecast fields of the Japanese Global Spectral model (JGSM). All forecast tracks extend to 72 h and the single letter labels correspond to the enlarged letter in model-selection buttons in the lower left.

Based on this discovery, the FTE statistics were recomputed with the SCON track set equal to NCON whenever the consensus spread was less than 250 n mi. For the resulting 31 cases at 72 h, the FTEs for CLIPER, JTWC, NCON, and SCON were 292, 217, 196, and 186 n mi, respectively. Of these 31 cases, SCON was equal to NCON (i.e., no model tracks rejected) 17 times. In the remaining 14 cases, for which the NPS team attempted to add value by not accepting NCON, the improvement of SCON relative to NCON at 72 h increases to 23 n mi (Fig. 3). Thus, the NPS team was able to detect model tracks with large errors such that the average SCON track error at 72 h was about 10% smaller than for the average NCON whenever the 72-h ensemble spread exceeded 250 n mi.

TRANSITIONS

The results of the SAFA beta-test (Carr et al. 2000a,b,c) were favorably received by the leadership of JTWC, thus warranting development (via SPAWAR funding) of the SAFA prototype into a fully operational expert system. SAFA Version 1.0 was completed and installed at JTWC in early July 2000. As of this writing, JTWC is having a potentially record-setting year in terms of track forecast accuracy.

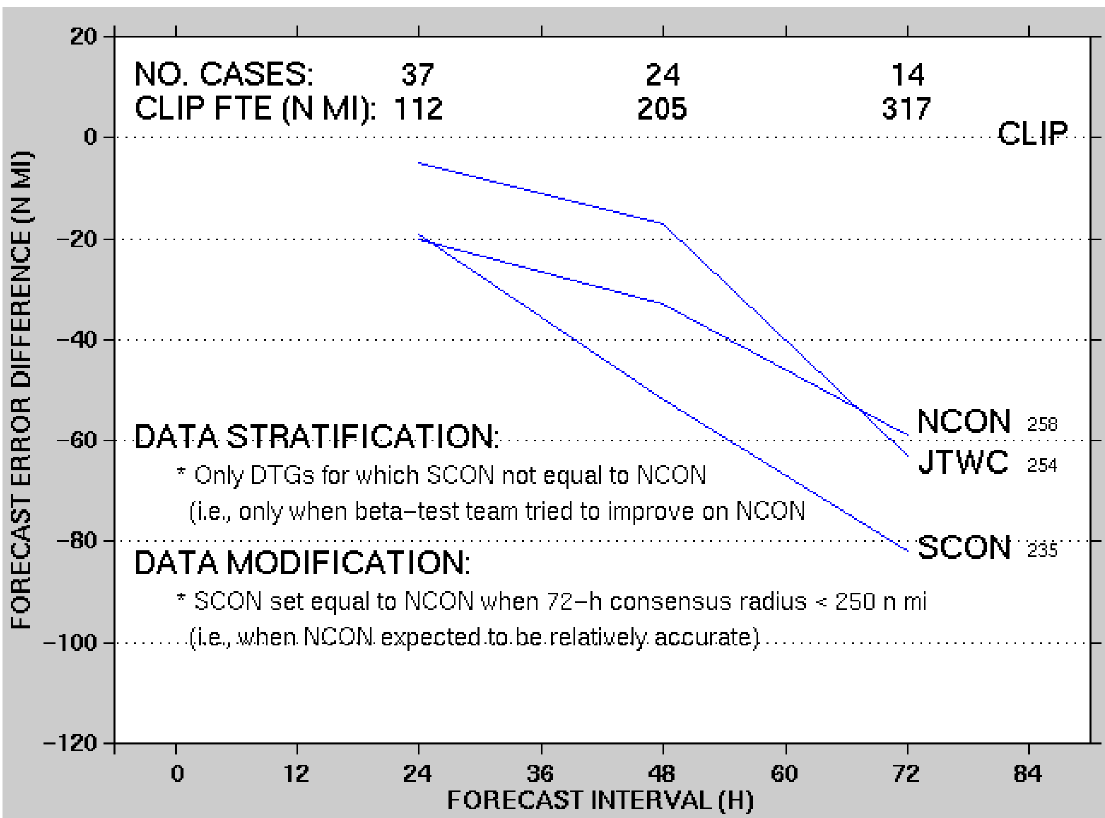

Figure 3. Skill (in n mi.) relative to the CLIPER forecast track errors (FTE) listed along the zero line for a homogeneous sample (number of cases indicated) from TC 19W through 30W during August-December 1999 for the Joint Typhoon Warning Center (JTWC), a non-selective consensus (NCON), and a selective consensus (SCON) track forecast by the NPS beta-test team.

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